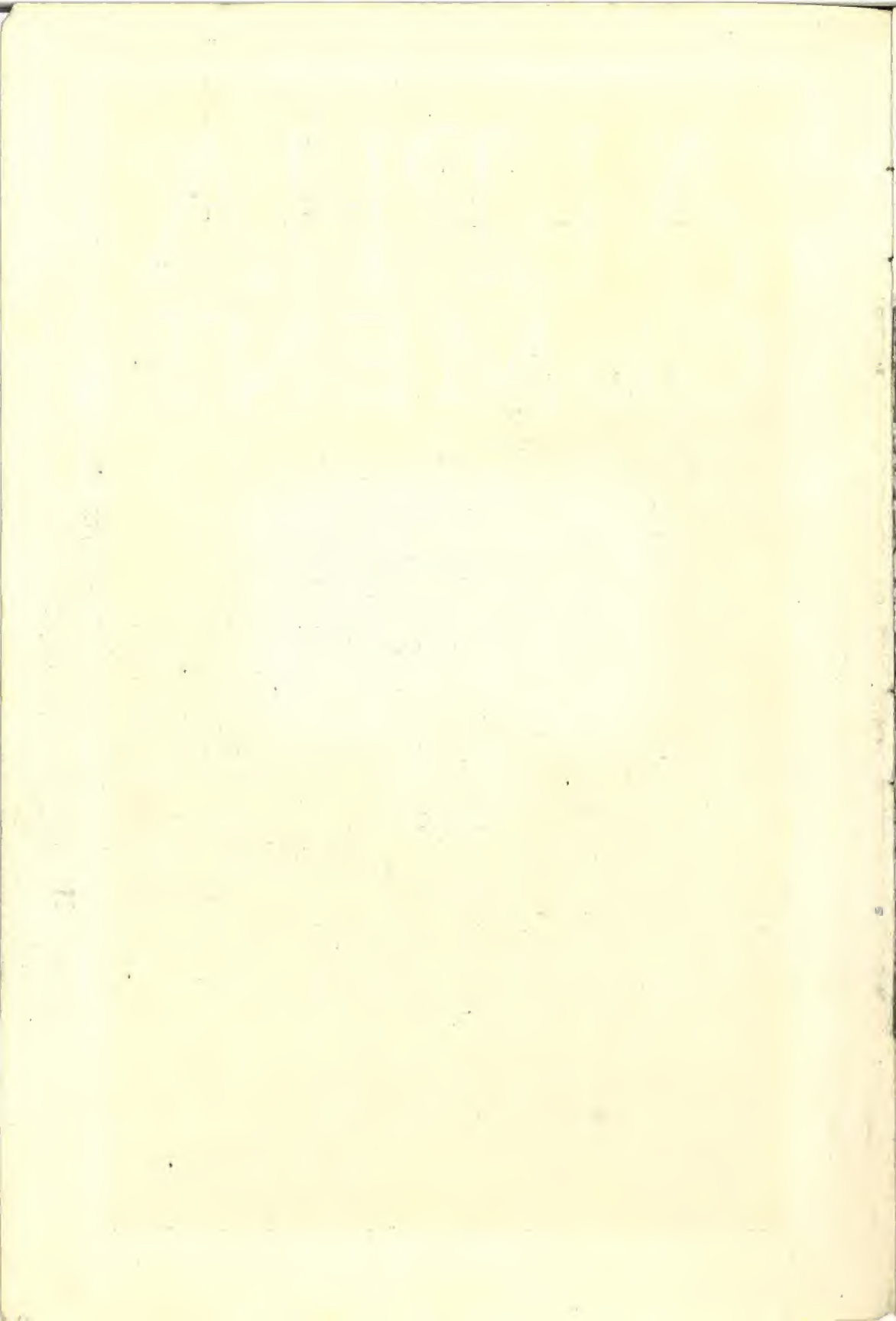


ALPHA CEMENT

Concreting in
Cold Weather



**ALPHA PORTLAND
CEMENT COMPANY**
EASTON, PA. CHICAGO, ILL.



Concreting in Cold Weather



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PORTLAND CEMENT ASSOCIATION

Seasonal Operation in the Construction Industries

In his foreword to the Report of a Committee of the President's Conference on Unemployment, entitled "Seasonal Operation in the Construction Industries," President Herbert Hoover, then Secretary of the Department of Commerce, said:

"CONSTRUCTION is the balance wheel of American industry. The value of yearly construction in the United States amounts to more than \$5,000,000,000 while the number of employes and independent workers engaged in construction, together with the workers of the material-producing industries, mounts into the millions.

"ACTIVITY in construction bears a close relation to general industrial conditions. The construction and equipment of new buildings result not only in the employment of building trades labor but in production of lumber, cement, iron and steel products, brick, sand and gravel, lime, hardware, paint, electrical equipment, furniture, textiles and a variety of other materials. If building falls off there is bound to be slackening in many other lines of industry, resulting in unemployment, decreased purchasing power of employes and further depression. The ebb and flow in the demand for construction, seasonally and between different years, thus to a large degree affect our economic stability.***** For most types of construction it is now possible to build the year 'round in all parts of the United States.*****

"THE need to eliminate the wastes of seasonal idleness has been brought forcibly to the attention of the construction industries and the public by reason of high labor costs and the failure of the building trades to attract young men into their ranks. Lengthening the building season will mean greater production from the men now engaged in the building trades and will also go far to attract capable apprentices.*****"

The following is quoted from the text of the report of the Committee:

"STEEL and concrete construction, with certain safeguards, can go forward at low temperatures. Methods of winter construction developed by leading contractors should now be greatly extended. Winter work is being done in some cases more cheaply than summer work, and in others at an increase in cost which is slight compared with the advantages of holding down the contractors' overhead expense by keeping his organization together, the shorter time that the owner's capital is tied up in the operation, and the earlier date at which occupancy is made possible."

Concreting in Cold Weather

Winter Work and the Contractor

WINTER work is not new or untried. Millions of dollars' worth of concrete construction is done each winter. Some contractors even prefer winter to summer concrete work. Labor, both skilled and unskilled is plentiful and the best can be had. Construction material is usually plentiful during the "slack months." The contractor's overhead expense is reduced by keeping his organization busy and his equipment and construction forces in action throughout the year. The extra cost for protection and heat is largely, if not all, compensated by



This 48-apartment building in Milwaukee was completed in time for spring occupancy because the work on the reinforced concrete structural frame was continued without interruption through January, 1923.

these advantages. The extra equipment for cold weather concreting is very simple but *no cold weather work should be attempted without it.*

The owner who has a building erected during the winter months has the advantage in letting a contract during the off season. He has, moreover, the important advantage of early occupancy.

Winter Work and the Owner

Frequently it is imperative to have a structure completed and ready for use at the earliest possible date. Schools, residences, apartment houses, office buildings and hotels are usually needed by a certain date. Earlier occupancy of such structures is of prime importance also from the investment standpoint.

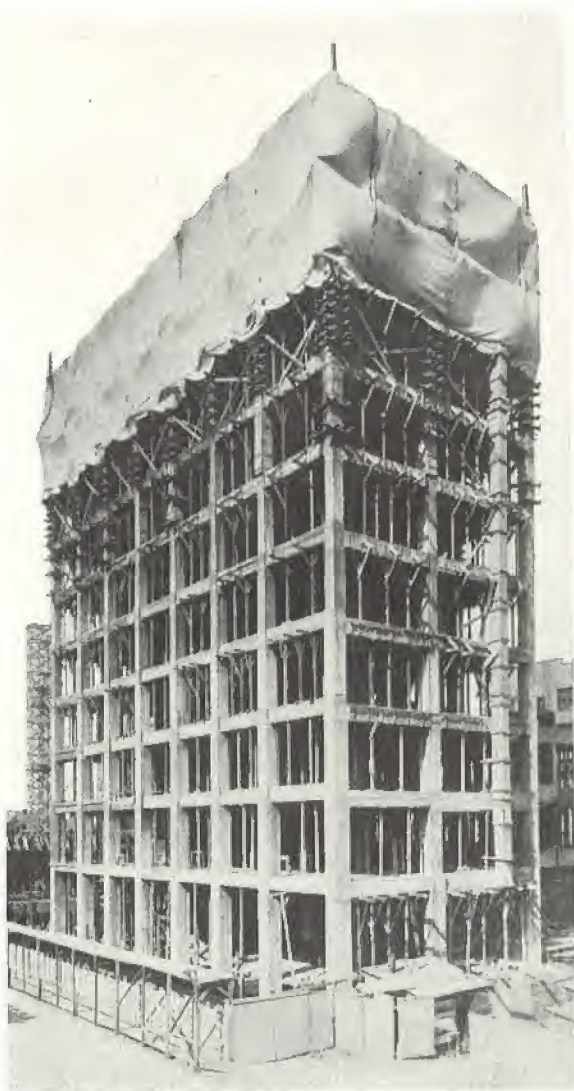
Money provided for building construction earns nothing for the borrower until it is represented as an investment in a completed structure, either rented or occupied by the business for which it is intended. It is often penny-wise and pound-foolish to delay the construction of a needed concrete building because of cold weather, for the extra cost

of construction in winter would often be more than offset by the interest saved on the money provided for its construction. The bonus or royalty often paid for the completion of a building before a specified time is tangible evidence of the value placed upon early occupancy by large corporations.

General Principles

The hardening of concrete is a chemical process. Like most chemical reactions this process requires heat. Furthermore, the hardening process is a gradual one, and continues for a considerable time. One of the fundamental things, therefore, about cold weather concreting, is heat—that is, control of temperatures. In general, the higher the temperature (within limits) the faster the hardening process goes on.

Another fundamental in every case of curing or hardening is that moisture *must* be available. The two fundamental factors in cold weather work therefore, are *heat and moisture*. The entire subject of cold weather concreting is encompassed in those two words. Heat that is without moisture, that causes rapid drying out, does not produce proper curing condi-

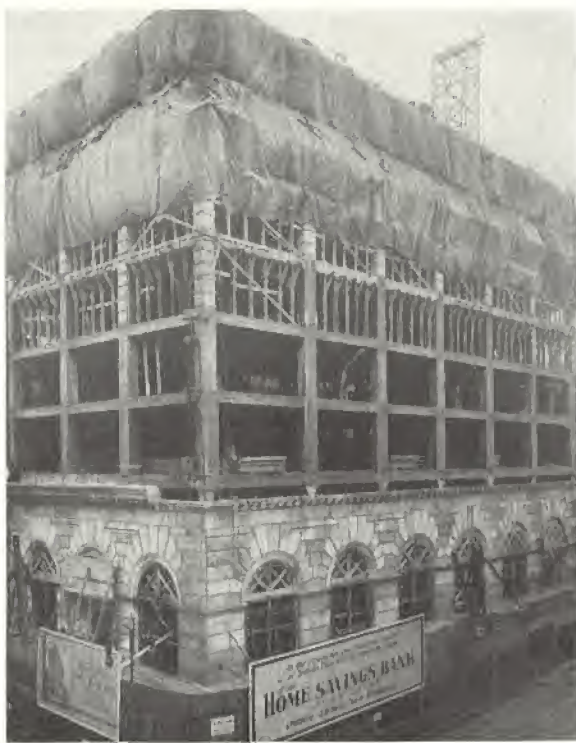


Cold weather need not delay the construction of tall buildings. The structural concrete frame of the ten-story Calgary Herald Building, Calgary, Alberta, was built at a time when the temperature was almost continuously below freezing.

tions. Rapid drying out may be mistaken for the completion of the hardening process. If the concrete is not kept moist during early hardening, its final strength will be less than maximum. It is especially important that moisture be supplied along with heat because of the relatively low moisture content of winter air.



Office building in Milwaukee built during the winter of 1926-27. Ample protection of the framework and interior enabled the construction to be carried on during cold weather without hardship.



A few precautions made it possible for the contractor to proceed with the construction of the Home Savings Bank in Toledo through the winter of 1923-24. Fresh concrete was well protected by tarpaulins which were overlapped generously to retain the heat furnished by salamanders.

If none of the mixing water evaporated or escaped after the concrete is placed, there would be more than enough present for complete hardening. The object of supplying moisture to the surface of fresh concrete is to prevent evaporation of contained water to a quantity insufficient for the hardening process. Warm, saturated air around the fresh concrete satisfies the conditions of curing.

It is a common phenomenon of chemical reactions that a certain temperature of the mixed substances must be established before the chemical action starts. Once started the action usually continues,

provided the rate of loss of heat does not exceed its rate of generation by the chemical action.

Thus, portland cement in the presence of moisture must have a certain temperature before the chemical process of hardening begins. However, the chemical process of hardening of cement goes on slowly, and if the heat loss by radiation is very rapid the chemical action will practically stop. Therefore, the first objective in cold weather con-



The concrete in the basement of the Agora Apartments, Lake Placid, N. Y., was placed January 13, 1923 and the sixth and last story was placed March 1st—a story per week—by the Turner Construction Company of New York. Temperature ranged from 26 degrees F. below zero to 15 degrees F. above.

creting is to place the material with sufficient contained heat to start the chemical action promptly and then to hold up the temperature so as not to stop or retard the hardening process. The concrete should not be exposed until a strength is attained which will permit the protective measures to be discontinued. By this time the density of the mass will be such as to hold a large part of the contained moisture in such a condition that it will not expand as ice when the concrete is subjected to low temperatures.

Bulletin No. 81 of the Engineering Experiment Station, University of Illinois, contains interesting data on the effect of low temperatures on the hardening of concrete. The data presented shows that some hardening may be expected at temperatures around 32 degrees Fahrenheit, but that the rate of hardening is slow. Some tests were also made to show the effect of alternate freezing and thawing on fresh concrete. The surface concrete of specimens subjected to repeated freezing and thawing attained practically no strength and the strength of the interior portion was only a small fraction of normal strength.

The general principles briefly stated above may be summarized as follows:

1. The hardening of concrete is a chemical process.
2. The temperature of the concrete should not be below a certain minimum (about 40 degrees F.) or the hardening process will not start properly nor will it continue at a normal rate.
3. Green concrete subjected to repeated freezing and thawing will not harden properly.
4. Fresh concrete frozen once, *may* gain its normal strength, but there is a strong presumption that it will not.
5. During the early stages of hardening, moisture is necessary, and care should be taken to prevent drying out.
6. It is inadvisable to subject green concrete to freezing temperature before it has attained more than one-fourth of its final strength.
7. There is nothing mysterious about successful cold weather concreting—it is simply a matter of keeping the concrete warm and moist. Any method of accomplishing this will produce satisfactory results.

Practical Rules for Cold Weather Work

Whenever work is started at such a season of the year that cold weather may be expected before completion of the work, provision should be made to quickly obtain and install enclosing and heating equipment.

Since the concrete should be placed at a temperature which will not delay initial hardening process, it is advisable to heat both aggregates and water. Simply heating the water but not the aggregates is not enough. The quantity of mixing water amounts to not more than about 20 per cent of the total volume of the materials and it is obvious that even though the water be introduced into the mixer at a temperature close to the boiling point, the resulting temperature of the hot water and cold aggregates mixed together will be but a relatively small fraction of the temperature of the water. If the temperature of the aggregate is below freezing, a certain amount of frost or ice will be present in them. This frost and ice and the cold aggregate will bring the resulting temperature of the mass below that at which the initial hardening will begin and progress normally. In order to insure prompt beginning of the hardening process, the mass should have a temperature of not less than 60 degrees F. when introduced into the forms, but not to exceed 140 degrees F. The maximum temperature of the mass should not be such as to produce too rapid evaporation of moisture.

There is only one way of knowing the temperature of the concrete as deposited in the forms and its temperature during the first five days after it is deposited, and that is by the use of thermometers. Recording thermometers should be used in the building at several locations and especially on the windward side of the enclosure. Common thermometers should be used to test the fresh mass. Such thermometers may be obtained at an insignificant cost and they constitute an essen-

Successful Methods for Concrete



← A coke-burning hot water heater is very convenient for heating water close to the mixer.

Another method of → heating materials by the use of a coal fire in a discarded hot water boiler seen in the lower left hand corner.



← Steam jets placed in aggregate pile to keep the material from freezing. Frozen lumps may also be thawed out by the use of these jets.

Special pipe grillage → for heating aggregates installed by Thompson Starrett Co., showing complete installation of pipes, boiler and mixer. Loaded trucks of sand and gravel were dumped directly onto this platform. This installation produced an aggregate with a temperature of approximately 70 degrees F. at all times.



← Water is heated here by a wood fire in the center of the pipe coil.

A heater made of → concrete block is used to warm the materials and mixing water on this concrete job.

Concrete Work in Cold Weather

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→ A heater made of concrete block is used to warm the materials and mixing water on this concrete job.

tial part of the equipment for cold weather concreting, because from the data given by them, absolute knowledge may be had as to whether or not the concrete has an opportunity to harden.

Table on page 14 was taken from data prepared by W. A. Hoyt, Consulting Engineer, Altoona, Pa., and used to serve as a guide for estimating the strength of the concrete at various periods of time. The table is based on tests recorded in Bulletin 81, Engineering Experiment Station, University of Illinois. Approximate additions to strength are given for mean temperatures of 40 degrees F. or more. In using the table the increments to strength for the mean daily temperature of the concrete for the period are added together. It is understood that the temperature of the concrete shall never be allowed to approach the freezing point and that no 24-hour period shall be counted as contributing to the strength of the concrete if the temperature reaches as low as 35 degrees F. (See table for example.)

Extremes of local climatic changes should be taken into consideration when providing necessary equipment. The speed with which the work is to be carried on should also be taken into account in deciding on the capacity of the heating equipment and the amount of housing material to be supplied. If it be desired to push the work rapidly, sufficient housing should be provided for at least three stories so that one story per week can be constructed.

Tarpaulins of canvas are the most convenient housing material to use. They should be sufficient to provide a tight connection at the lowest floor housed and to completely cover the last floor cast and allow ample room between the canvas and this floor for circulation of heat. Positive provision should be made to allow circulation of heat. It is not enough to insulate the top surface of a green floor and expect that floor to be warm throughout its thickness by absorption of the heat through the slab. Canvas should be carried entirely outside of the limits of the new floor slab so that heat can pass up to the top of the floor. In addition to this, heat openings should be provided in the floor so that the warm air may pass directly to the top surface of the slab. These openings, of course, are later



Salamanders under forms and behind canvas furnish heat for freshly placed concrete and maintain constant temperature.

filled with fresh concrete. They should preferably be placed at about the mid-point of panels and are conveniently formed by using a box in the form of a truncated pyramid, with the small base resting on the floor forms. If steam heat is used, pipes should be run between the top canvas and floor, in which case heat holes are not necessary.

With sufficient tarpaulins for three floors, building operations can be carried on continuously and one story cast per week. The side tarpaulins should be up while the green concrete is being cast and just as soon as each portion of the story is completed, it should be enclosed and heat turned in.

The use of salamanders for supplying heat is very common. There is, however, no certainty as to the quantity of heat supplied by salamanders. They may be fired regularly and with high grade fuel or just the reverse. The gases of combustion and smoke as well as the ashes produced by salamanders are also troublesome. Since in cold weather work live steam is usually necessary for thawing out aggregates, heating water, etc., it appears that steam provides the best character of heat. The only objection to the use of steam heat is, of course, the necessary piping, but since the steam is used at a low pressure, the piping need not be perfectly tight and the lightest weight of pipe obtainable may be used. Steam should be allowed to escape within the enclosure to provide moisture in the air and on the surface of the concrete. The running of such heating pipe is a simple matter, and if the succeeding floors are symmetrical, as is usually the case, no additional pipe cutting will be required for upper floors. It is well to provide several risers so that one or more of them can be shut off while the heating pipe is being moved up, or turned on immediately after casting a section of a floor. Since the steam pressure is low, neither a high pressure nor a new boiler is required. An old boiler of 20 to 30 horsepower will furnish sufficient steam for the cold weather construction of a building of 5000 sq. ft. floor area.

Heating aggregates with steam is best accomplished by the use of grillages of pipes over which the aggregates are piled. During the time when aggregates are not being unloaded onto the grillages, the piles of aggregates should be enclosed or covered so as to retain the heat. It is usually possible to so locate these grillages that the aggregates can be shoveled from the bottom of the pile practically under cover and transported to a mixer located in the basement of the building, so that comparatively little heat will be lost.

A convenient method of heating water is by means of a steam pipe passed into a tank of water from which the mixing water is drawn.

The forms must be free from snow, ice and frost and should be reasonably warm. Live steam is an effective agent for cleaning and heating forms.

Large masses of fresh concrete are obviously better able to withstand low temperatures than thin slabs or beams. Thus, for bridge abutments and piers it is often sufficient to place the concrete at a temperature of 60 to 70 degrees F. and cover the work to reduce heat loss. If the hardening process attains a normal rate and the work is

covered, the heat generated by the chemical action will be sufficient to hold up the temperature for several days. However, in buildings where relatively thin members only are used, the heat generated by the hardening process should never be depended upon as sufficient.

It is to be regretted that so much gambling with the weather has been indulged in in the past. Especially so, when the methods of cold weather concreting are so simple and so well understood by experienced contractors. It is possible that some contractors have been moved to take chances by the fact that reinforced concrete buildings have been successfully constructed during cold weather without any protection whatever. Many cases have been reported in which concrete has been frozen for a considerable length of time and has thoroughly hardened on thawing out. The assumption that this fortunate result will always follow should never be made. It has resulted in some very unfortunate collapses. The additional expense necessary to make sure and certain that cold weather will not affect the strength or safety of the building, either during or after its construction, is so insignificant that contractors who desire to protect their reputation and the lives of their workmen as well as save themselves from loss, should never neglect to provide the simple equipment required.

The Portland Cement Association will gladly furnish a list of technical articles on cold weather work and advise engineers, architects and contractors on methods to use in special cases.



Winter construction on north caissons, Philadelphia anchorage, Delaware River bridge, Philadelphia, in 1923. Tarpaulins are used to protect the freshly placed concrete in the background.



Construction of this concrete chimney was not interrupted by cold weather. The canvas envelope protected the work completely and the interior was kept warm by a salamander located in the base of the chimney.



Sand storage bin at the plant of the Hawthorne Roofing Tile Company, Cicero, Illinois. This structure was built without interruption during cold weather.



Construction of the Nicollet Avenue bridge in Minneapolis was carried on through the winter. Ample protection is given to the concrete arch in the foreground.

**APPROXIMATE DAILY INCREASE IN STRENGTH OF
CONCRETE DESIGNED TO PRODUCE A COMPRESSIVE STRENGTH
OF 2000 LB. PER SQ. IN. AT 28 DAYS***

(Use proportionally higher increments for
higher strength concrete)

Mean Daily Temp. Degrees F.	AGE IN DAYS									
	1	2	3	4	5	6	7	8	9	10
40	95	88	70	65	56	54	52	50	47	45
44	112	93	75	66	60	56	52	51	48	47
48	133	95	79	68	61	58	54	53	51	49
52	155	100	81	69	63	61	57	55	52	50
56	175	110	83	70	66	63	59	59	54	51
60	195	122	85	71	68	65	63	60	56	53
62	204	124	87	72	70	66	63	60	56	53
64	213	126	90	74	71	67	63	60	56	53
66	222	128	93	76	73	68	63	60	57	53
68	230	130	96	78	74	69	64	60	57	53
70	240	130	100	80	75	70	65	61	57	53

Mean Daily Temp. Degrees F.	AGE IN DAYS										
	11	12	13	14	15	16	17	18	19	20	21
40	43	40	39	37	33	30	30	27	25	23	22
44	45	43	40	38	34	32	30	27	25	23	23
48	48	45	42	41	37	34	31	28	25	24	23
52	48	46	43	42	38	35	31	30	28	26	24
56	49	46	44	42	38	35	31	30	30	27	26
60	50	46	44	42	38	35	32	30	30	29	28
62	50	46	44	42	38	35	32	31	30	29	28
64	50	46	44	41	38	36	33	31	30	29	28
66	49	46	44	41	38	36	33	32	30	29	28
68	49	46	44	41	38	36	34	32	30	29	28
70	49	46	44	41	38	36	34	32	30	29	28

Example—

It is desired to estimate from the table the approximate strength at five days of concrete which has been subjected to the mean daily temperatures given:

1st day	54 degrees F.	Increment from table	155 (Taken for 52 degrees)
2d	" 48 " F.	" " "	95
3d	" 60 " F.	" " "	85
4th	" 52 " F.	" " "	69
5th	" 44 " F.	" " "	60

Total.....464 lb. per sq. in.

This is less than $\frac{1}{4}$ of 2000, or 500 lb. per sq. in. and the heating should be continued.

*This table was prepared by W. A. Hoyt, M.A.S.C.E., consulting engineer, Altoona, Pa., from the results of tests at the Engineering Experiment Station, University of Illinois, Urbana, Ill.

Practical Points for Cold Weather Work

1. Always be prepared to enclose the work and supply heat whenever work that may run into cold weather, is begun.
2. Aggregates are heated to best advantage by 1½-inch steam pipes laid as a grill under the piles or by a 6-ft. length of perforated steam pipe, inserted into the pile.
3. Water is heated by running a 1½-inch steam pipe into the water barrel.
4. A 50-horsepower boiler, carrying 50 to 60 pounds of steam is required for a large job, but an 18 to 25-horsepower boiler is sufficient for jobs of not more than 5000 square feet of floor area.
5. One salamander is usually sufficient for 300 square feet of floor area and a heat hole should be provided for each salamander.
6. Columns should be concreted at the same time as the floor and column tamping continued for an hour or more after the floor is concreted.
7. Bases of exterior columns are most difficult to protect and in extremely cold weather a salamander should be placed on each of two sides of exterior columns.
8. For unusual speed or cold weather, or when monolithic walls are carried up, the lower floor should be curtained and salamanders placed at exterior columns.
9. Apply fuel to salamanders frequently and in small quantities, to minimize smoke and provide uniform temperature.
10. Water barrels should be provided to extinguish fires and care taken to keep canvas from blowing against salamanders.
11. A detailed temperature record should be kept showing date, hour, outside temperature, temperature at bottoms of columns, underside of slab, under the canvas over the slab, temperature of concrete as deposited and, especially, temperature at bases of exterior columns on windward side of building.
12. Aim at a minimum temperature of 60 degrees F. within the enclosure for five days. During protracted cold weather keep the tarpaulins up and maintain a temperature of not less than 40 degrees F. for ten days additional.
13. Use table on page 14 as a guide to the strength of the concrete, omitting twice the period of time that the concrete is below 35 degrees F. Do not remove permanent shores until the strength is shown to be three-fourths the design-strength of the concrete.
14. Do not depend on anti-freezing compounds instead of *protection and heat*. Accelerators do not furnish heat to start the hardening process, but once started, accelerators will cause the concrete to gain strength faster *if it is kept warm*. No accelerators or anti-freezing compounds should be used that will decrease the final strength of the concrete, promote rusting of reinforcement or produce efflorescence.

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Industrial Buildings
School, Hotel and Office Buildings
Public Works
Roads and Streets
Railways
Agriculture
Town and Country Homes

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